Retrieving Cloud and Aerosol Properties from the ARM Raman Lidar

Research Highlight

Several studies have demonstrated that the ARM Raman lidar (RL) is capable of making high-quality observations of clouds, especially high cirrus clouds (e.g., Thorsen et al. 2013b). However, the identification of clouds is treated in a simple manner in current ARM RL value-added products (VAPs) that originally were designed with a focus on water vapor and aerosols. To fully realize the potential of the instrument, Thorsen et al. (2015) and Thorsen and Fu (2005) have developed a completely redesigned automated Feature (i.e., cloud and aerosol) detection and EXtinction retrieval (FEX) algorithm for the ARM RL.

FEX identifies features in all the various quantities that can be measured by the RL: scattering ratios derived using elastic and nitrogen channel signals from two fields of view, the scattering ratio derived using only the elastic channel, and the total volume depolarization ratio. Range-dependent context-sensitive detection thresholds for each quantity are determined by calculating the expected clear-sky signal and noise. The use of multiple quantities provides a more complete depiction of the vertical and temporal extent of clouds and aerosols and allows for consistency checks to improve the accuracy of the feature mask. FEX makes significant improvements over the existing RL VAP cloud masks, particularly for cirrus cloud detection (Figure 1).

Extinction coefficient profiles of clouds and aerosols are typically the quantity of most interest from lidars. However, lidars fundamentally measure backscattered energy, not extinction, and for widely prevalent single-channel elastic backscatter lidars, extinction must be obtained by assuming the ratio of particulate extinction to backscatter (i.e., the lidar ratio). An RL is an advanced lidar that intrinsically separates signals from molecules and particulates (i.e., clouds and aerosols), allowing profiles of extinction coefficients to be retrieved directly. While this technique is highly accurate, the retrieval is performed using signals from Raman-scattered light that is a weak scattering process. FEX uses an adaptive smoothing approach to overcome this random noise, thereby extending extinction retrievals to more features. These directly retrieved extinction profiles using the Raman method are supplemented by other retrieval methods developed for elastic backscatter lidars. Portions of features where the lidar ratio can be obtained are used to infer the lidar ratios for the regions where no such estimate can be made. A comparison between aerosol optical depth from FEX and that from collocated sun photometers over multiple years shows agreement in terms of bias error of approximately 0.3% and 4.3% at the Southern Great Plains (SGP) and Tropical Western Pacific sites, respectively.

Because one of the focuses of FEX is to obtain cloud extinction (something the current VAPs do not do), it was necessary to include a treatment for multiple scattering. Thorsen and Fu (2015) formulated a new way of solving for multiple scattering that accounts for its effect in all of the RL channels in each range bin. FEX also includes a classification of feature type which identifies aerosol, rain, liquid cloud, ice cloud, and horizontally-oriented ice. The classification scheme leverages the atmosphere's thermodynamic state and the feature's scattering properties (i.e., lidar ratio, backscatter, and depolarization). Figure 2 shows example output from the FEX algorithm applied to the ARM RL on May 10, 2011, at the SGP site.

This work has greatly improved the quality of aerosol and cloud data available from the ARM RL and adds to the unique measurements made by this system. The continuously operated, automated ARM RLs provide an enormous wealth of water vapor, temperature, aerosol and cloud data that is unmatched outside the ARM Facility. Work has begun to run FEX operationally within the ARM Data Management Facility, with the output being made available to the general user community through the ARM Data Archive.

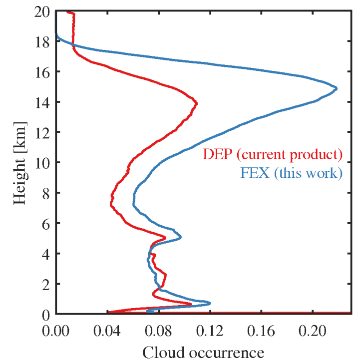

Figure 1. The cloud occurrence profile from the current ARM DEP product (red) and from the new FEX algorithm (blue) developed in this work at Darwin from December 2010 through December 2014.

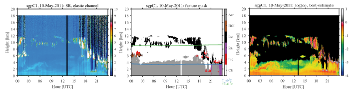

Figure 2. Example output from the FEX algorithm on May 10, 2011, at the SGP site. The scattering ratio on the left; feature classification mask with pixels classified as either liquid cloud (red), rain (purple), ice (black), horizontally oriented ice (brown), or aerosol (gray) in the center; and the extinction coefficient on the right.

Reference(s)

Thorsen TJ, Q Fu, RK Newsom, DD Turner, and JM Comstock. 2015. "Automated retrieval of cloud and aerosol properties from the ARM Raman lidar, part 1: feature detection." Journal of Atmospheric and Oceanic Technology, , doi:10.1175/JTECH-D-14-00150.1. ONLINE.

Thorsen TJ and Q Fu. 2015. "Automated retrieval of cloud and aerosol properties from the ARM Raman lidar, part 2: extinction." Journal of Atmospheric and Oceanic Technology, , doi:10.1175/JTECH-D-14-00178.1. ONLINE.

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Working Group(s)

Aerosol Life Cycle, Cloud Life Cycle